Coastal Engineering Technical Note

LONGSHORE TRANSMISSION OF REFLECTED WAVES

PURPOSE: To provide guidance requested by Corps field offices on longshore transmission of waves reflected from Coastal Structures.

GENERAL: Waves reflected from coastal structures may become trapped by refraction, causing reflected wave energy to arrive at the coastline some distance from the structure. Trapped reflected waves have been previously discussed by Camfield (1982, 1988), and in and in the Shore Protection Manual (SPM, 1984). The reflected waves may have a localized effect on coastal processes, and cause localized erosion as the shoreline adjusts its orientation to reach equilibrium with the reflected waves. Reflected waves may also affect recreation, e.g., surfing, and there is an increasing interest to analyze reflected waves. Figure 1 is a general definition sketch for a reflected wave.

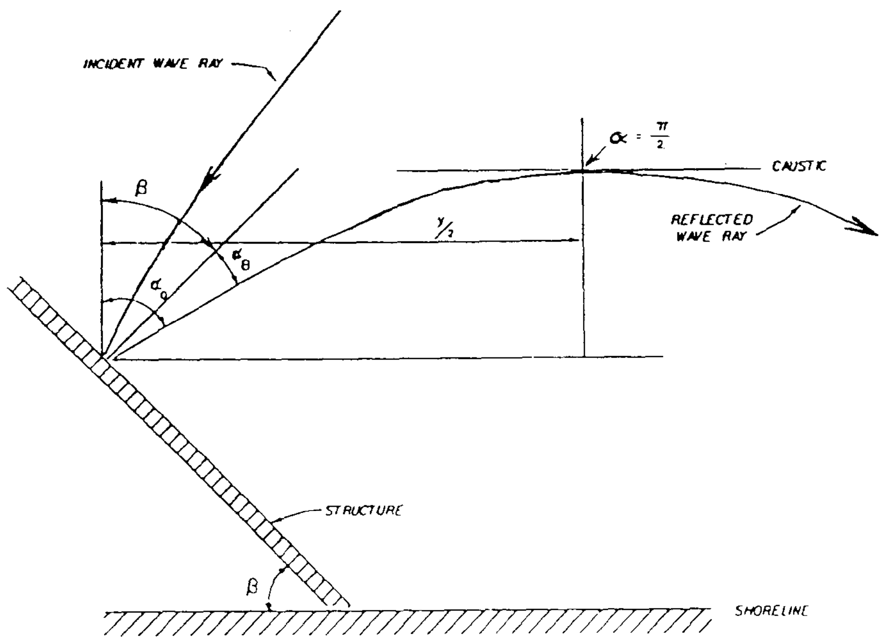

Figure 1. Wave reflected from a structure.

A more exact solution for a reflected wave traveling over non-uniform topography would require a numerical refraction program. However, a quick, approximate solution can be obtained by making simplifying assumptions of a locally straight shoreline and a seabottom that is a plane slope, S, extending normal from the shoreline. Assuming symmetry, the reflected wave in that case will travel a distance of $y/2$ in the longshore direction before turning shoreward at a caustic (Figure 1), and travel a total distance y before returning

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14. ABSTRACT
Waves reflected from coastal structures may become trapped by refraction, causing reflected wave energy to arrive at the coastline some distance from the structure. Trapped reflected waves have been previously discussed by Camfield (1982, 1988), and in and in the Shore Protection Manual (SPM, 1984). The reflected waves may have a localized effect on coastal processes, and cause localized erosion as the shoreline adjusts its orientation to reach equilibrium with the reflected waves. Reflected waves may also affect recreation, e.g., surfing, and there is an increasing interest to analyze reflected waves.

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to a water depth, h_s, the depth of water at the point of reflection from the structure. A relationship can be developed to determine the distance, y. Camfield (1982) and the SPM (1984) previously presented a simplified solution for shallow water waves which ignored effects of wave period, T. This results in an over-prediction of refraction, particularly for shorter period waves. A solution that includes the wave period is presented herein.

At any point along a reflected wave ray, Snell's Law gives

$$L = L_s \frac{\sin \alpha}{\sin \alpha_o} \tag{1}$$

where L_s is the wavelength of the reflected wave at the point where it is reflected from the structure, α_o is the angle of reflection with respect to the normal to the shoreline, L is the wavelength at some point along the wave ray, and α is the angle with respect to the normal at that point. The wave dispersion equation gives

$$h = \frac{L}{2\pi} \tanh^{-1}\left(\frac{L}{L_o}\right) \tag{2}$$

where L_o is the deepwater wavelength and h is the water depth at the point where the wavelength equals L. The x coordinate, measured seaward from the shoreline, of a point on the wave ray is then

$$x = \frac{L_s \sin \alpha}{2 \pi S \sin \alpha_o} \tanh^{-1}\left(\frac{L_s \sin \alpha}{L_o \sin \alpha_o}\right) - \frac{h_s}{S} \tag{3}$$

Defining a constant, K

$$K = \frac{L_s}{L_o \sin \alpha_o} \tag{4}$$

and differentiating x with respect to α, gives

$$dx = \frac{L_o}{2\pi S}\left\{K \cos \alpha \tanh^{-1}(K \sin \alpha) + K^2 \sin \alpha \cos \alpha \left[1-(K \sin \alpha)^2\right]^{-1}\right\} d\alpha \tag{5}$$

but $dx = dy \cos\alpha / \sin\alpha$, so that

$$dy = \frac{L_o}{2 \pi S}\left\{K \sin \alpha \tanh^{-1}(K \sin \alpha) + (K \sin \alpha)^2 \left[1 - (K \sin \alpha)^2\right]^{-1}\right\} d\alpha \tag{6}$$

Noting that L_o is given by

$$L_o = \frac{gT^2}{2\pi} \tag{7}$$

this then can be written as

$$\frac{yS}{gT^2} = 0.05066 \int_{\alpha_o}^{\pi/2} \{K \sin\alpha \tanh^{-1}(K \sin\alpha) + (K \sin\alpha)^2 [1 - (K \sin\alpha)^2]^{-1}\} \, d\alpha \quad (8)$$

Solutions for Equation 8 can be obtained numerically and are plotted in Figure 2.

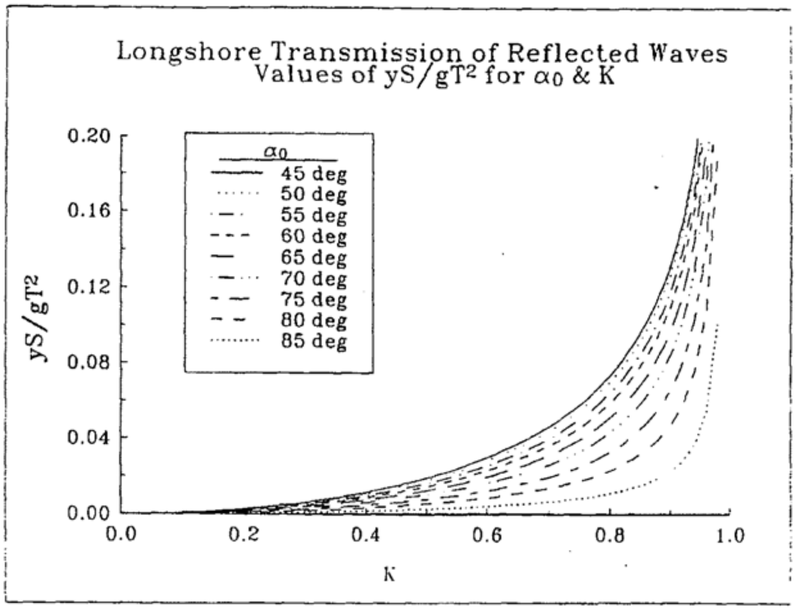

Figure 2. Solutions for longshore distance, y.

<u>ADDITIONAL INFORMATION:</u> For additional information contact Mr. Michael J. Briggs, Coastal and Hydraulics Laboratory at (601) 634-2005 or Michael.J.Briggs@erdc.usace.army.mil

********************************EXAMPLE**********************************

A breakwater extends from the shoreline at a 45 degree angle. (β in Figure 1) Waves with periods of 8 seconds and 12 seconds reflect from the breakwater at a 20 degree angle to the right of the normal to the breakwater (**α_β** in Figure 1). The water depth at the breakwater is 30 feet, and the bottom slope, ***S*** is 0.01. Determine the distance, y, that the reflected waves travel in the longshore direction.

From Fig. 1, $\boldsymbol{\alpha_O}$= 45º + 20º = 65°

The 8 second wave has a deepwater wavelength of 328 feet, and the 12 second wave has a deepwater wavelength of 738 feet. For the 8 second wave, from Table C-l in the Shore Protection Manual (SPM, 1984),

$d_s / L_o = 30 / 328 = 0.09146$ giving $d_s / L_s = 0.1335$

so that

$$K = L_s / (L_o \sin \alpha_o) = 0.9146 / (0.1335 \times 0.9063) = 0.756$$

and from Fig. 2

$$y S / g T^2 = 0.040$$

so that

$$y = 0.040 \times 32.2 \times 64 / 0.01 = 8{,}240 \text{ feet}$$

For the 12 second wave, from Table C-1 in the SPM,

$d_s / L_o = 20 / 738 = 0.04065$ giving $d_s / L_s = 0.08402$

so that

$$K = 0.04065 / (0.08402 \times 0.9063) = 0.534$$

and from Fig. 2

$$y S / g T^2 = 0.014$$

so that

$$y = 0.014 \times 32.2 \times 144 / 0.01 = 6{,}490 \text{ feet}$$

As expected, the longer period wave is refracted more than the shorter period wave.

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